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United States Environmental Protection Agency	Office of Solid Waste and Emergency Response	Pub. 9355.08FS PB 93-963359 July 1994

SUPERFUND REMEDY IMPLEMENTATION GUIDE: THERMAL DESORPTION TREATMENT

Office of Emergency and Remedial Response
Hazardous Site Control Division 5302G

Quick Reference Fact Sheet

Section 121(b) of the Comprehensive and Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 mandates EPA to select remedies that "are protective of human health and the environment,....and that utilize permanent solutions and alternate treatment technologies or resource recovery technologies to the maximum extent practicable." Thermal desorption is being utilized increasingly at Superfund sites to remove bound or mixed organic contaminants (including volatiles, semivolatiles, and chlorinated pesticides) from soils, sediments, sludges, and other media. This guide provides an overview of key considerations that need to be addressed during the Remedial Design and Remedial Action to ensure that desorbers are operated in a manner that represents good operating practices and provides assurance that their operation is protective of human health and the environment.

Thermal desorbers are classified under the Resource Conservation and Recovery Act (RCRA) as an incinerator, boiler, or industrial furnace, or "Miscellaneous Units." This guide addresses thermal desorbers that do not meet the RCRA definition (under 40 CFR 260.10) of an incinerator, boiler, or industrial furnace, but meet the definition of a Miscellaneous Unit. Henceforth, in this guide, the term "thermal desorber" is used to refer to such desorbers. Although this guide provides some clarifying examples of thermal desorbers, a regulatory distinction regarding whether specific thermal desorbers are incinerators or other regulated facilities is beyond the scope of this guide. This guide highlights the most common operational characteristics associated with thermal desorbers, outlines recommended testing and operational control parameters, and presents residual and air emissions concerns. The guide also provides a list of technical resources in the form of references to written documents and key contact phone numbers. It is recommended that project managers consult with contacts identified in this document if issues arise regarding the design or operation of a thermal desorption unit at a Superfund site.

- Thermal Source -- The source(s) of heat for volatilization of organics in these systems is typically derived from burning fossil fuels or by utilizing electric power.

- Thermal Source Location -- Thermal desorbers are generally indirectly heated (i.e., heat is conducted through the walls of a chamber that contains the waste to be treated).

The design characteristics exhibited by individual desorbers comprise a broad spectrum ranging from those understood to be associated with thermal desorbers that should be clearly classified as RCRA Miscellaneous Units to desorbers that are classified as RCRA incinerators, boilers, or industrial furnaces. The key regulatory distinction between a desorber that is classified as a Miscellaneous Unit rather than an incinerator, boiler, or industrial furnace, is the degree that the desorber is direct-flame fired and the type of APCDs used (e.g., use of destructive control devices such as thermal combustors for off-gas typically associated with incinerators).

Highlight 1 defines a subset of units that are clearly associated with thermal desorbers and not thermal destruction units. This subset is not an exhaustive or exclusive listing of characteristics and the determination will need to be made on a case-by-case basis for those units that meet some but not all of the above criteria.

HIGHLIGHT 1

THERMAL TREATMENT UNIT CHARACTERISTICS

Characteristics of units that may be classified as thermal desorbers are:

Thermal Desorption Chamber:
- Indirect-fired heat source used for desorption chamber(s).

Air Pollution Control Devices (APCDs):
- Indirect-fired heat source used for APCDs.
- Capture/recover a significant portion of contaminants (e.g., condensation or adsorption).
- APCDs not utilizing controlled flame combustion.

Waste Residual Management:
- Treatment of residuals is separate from the thermal desorber.

GENERAL CHARACTERISTICS OF THERMAL DESORBERS

Thermal desorption is a separation or extraction process, the primary function of which is to remove bound or mixed organic contaminants from a waste matrix (soil, sludge, etc.) using a thermal source. While these desorbers use thermal energy, they are designed as separation devices, not thermal destruction devices (although some degree of thermal destruction may occur) or units specifically addressed as incinerators or boilers and industrial furnaces under RCRA. A general description of thermal desorbers is as follows:

- Principle of Operation -- Thermal energy is used to volatilize organic constituents in a medium (e.g., soils, sludge, etc.). The vaporized contaminants are generally captured and routed to a separate treatment train (see next bullet). In addition to volatilizing constituents in the waste medium, the thermal desorption process may also result in the partial breakdown of compounds and reformation of new compounds, which can potentially result in formation of new contaminants of concern (i.e., dioxins and furans) in the treatment residuals.

- Volatilized Organic Residuals -- The off-gas containing the volatilized contaminants from the waste matrix is generally captured via condensation or adsorption (e.g., activated carbon). The condensate or spent adsorbent is then typically transported off-site for reuse, treatment or disposal. Air, combustion gas, or inert gas is used to transport the volatilized components to air pollution control devices (APCDs) such as those mentioned above, and the transporting medium is generally vented to the atmosphere.

- Air Emissions -- APCDs typically include a variety of techniques to remove components of air pollutants (organics, particulates, metals) prior to recycling or venting to the atmosphere.

- Volatilization Conditions -- Thermal desorption is generally designed to have operating conditions (e.g., temperature range, transporting gas, etc.) that favor volatilization of contaminants rather than destruction (i.e., combustion). The process(es) for volatilizing organics may occur under a variety of oxygen or air concentrations and temperature ranges, and may include blanketing with nitrogen to further impede combustion.

- Unit Design -- Thermal desorbers might be composed of one or more enclosed treatment stages. Refractory lining may not be present depending on the temperature of operation.

SUPERFUND REQUIREMENTS

Section 121(b) of CERCLA as amended by SARA of 1986 mandates the EPA to select alternatives that are protective of human health and the environment, and provides a listing of factors that should be considered in assessing remedial alternatives. 40 CFR 300.430 outlines nine remedy selection criteria that encompass the statutory requirements of Section 121(b). These criteria are divided into three categories: threshold criteria, primary balancing criteria, and modifying criteria. For the purposes of this guide, the threshold criteria will be highlighted as critical considerations for thermal desorption at a Superfund site. The threshold criteria are: (1) Overall protection of human health and the environment (see Highlight 2) and (2) Compliance with applicable or relevant and appropriate requirements (ARARs). Principle ARARs for thermal desorbers are generally RCRA regulations.

HIGHLIGHT 2

Remedy selection, design, and operational requirements for treatment equipment, including thermal desorbers, must be based on what is necessary to ensure protection of human health and the environment.

RCRA Regulatory Requirements:

RCRA regulations that establish operational, design, and emission standards for thermal treatment units have important implications for thermal desorbers. Thermal desorbers that process RCRA waste are subject to regulations as follows: (1) thermal desorbers that are classified as Miscellaneous Units are subject to 40 CFR 264 Subpart X; (2) thermal desorbers that are classified as incinerators are subject to 40 CFR 264 Subpart O; and (3) thermal desorbers that are classified as boilers or industrial furnaces are subject to 40 CFR 266 Subpart H. If a desorber is not known to be treating a RCRA waste, then the appropriate RCRA regulations for the device may be ARARs.

Incineration standards (40 CFR 264 Subpart O) apply to devices with the flame in the thermal desorption chamber(s) (i.e., direct-fired devices) or with direct-fired APCDs if treating RCRA hazardous waste. If the device has the flame outside the thermal desorption chamber(s) (i.e., indirect-fired devices) or has an indirect-fired APCD, pertinent 40 CFR 264 Subpart O requirements may apply, as determined on a case-by-case basis.

This fact sheet is primarily directed at those desorbers that are not subject to incinerator or boiler and industrial furnace standards; therefore, these standards are not discussed in detail in this guide.

RCRA 40 CFR 264 Subpart X

Standards for miscellaneous units might be ARARs for thermal desorbers that are not subject to either the RCRA incinerator or boiler and industrial furnace standards. Additionally, the 40 CFR 264 Subpart X regulations require inclusion of provisions of 40 CFR 264 Subpart I (container standards) through 40 CFR 264 Subpart O (incinerator standards) of this subpart that are appropriate. The primary criterion for determining what standards are appropriate is the degree to which the standards are needed to ensure protection of human health and the environment.

40 CFR 264 Subpart X regulations require that miscellaneous units be designed, operated, and closed in a manner that is protective of human health and the environment. 40 CFR 264.601, states that the protection of human health and the environment includes the following:

a. Prevention of releases that may have adverse effects on ground water or surface water;

b. Prevention of releases that may have adverse effects due to migration of waste constituents to surface water, wetlands, or on soil surfaces; and

c. Prevention of releases that may have adverse effects due to migration of wastes in the air.

A site-specific risk assessment may be needed to ensure that the design, operation, and closure of the thermal desorption unit is protective. Risk assessments might include assessments of media potentially affected by the operation of a thermal treatment unit as described above. However, a full discussion and guidance on completing risk assessments for thermal desorbers is beyond the scope of this guide.

Other Regulatory Considerations: Toxic Substances Control Act (TSCA)

The Toxic Substances Control Act (TSCA) regulations will be applicable when disposal of material contaminated with PCBs at concentrations of 50 ppm or greater occurs. Treatment options for PCB-contaminated materials are governed by the type of medium contaminated (e.g., soil, sediment, sludge, etc.) and the concentration of PCBs in the medium. The three treatment options available for these wastes are: (a) incineration and high efficiency boiler; (b) treatment with a technology that can achieve a level of

performance equivalent to incineration; and (c) disposal in a TSCA-approved chemical waste landfill.

Thermal desorbers used for disposal (i.e., treatment) of PCBs, which do not meet the definition of an incinerator, are administered as alternative methods of destroying PCBs pursuant to 40 CFR 761.60(e). The regulations require that all alternative methods of disposal must: (1) demonstrate the capability of achieving a level of performance equivalent to incineration or high efficiency boiler under 40 CFR 761.70 and 761.60, respectively; and (2) establish that the method does not present an unreasonable risk of injury to human health or the environment. The specific requirements for alternative technologies will be made on a case-by-case basis.

OPERATIONAL CONTROLS

The operation of the thermal desorber should be controlled during the shake-down mode, proof-of-performance (POP) test, post-POP test period (time during which performance data are evaluated), and continued operation. Control conditions during these periods may include continuous monitoring as well as batch testing of untreated wastes, treated wastes, and process residues.

Engineering analysis of individual thermal desorption systems and results of POP tests, combined with expert engineering judgment, should generally indicate appropriate operating controls for a given unit such that the unit effectively treats contaminants of concern while operating under conditions protective of human health and the environment. The case-by-case examinations should focus on the design and operating functions of a given thermal desorber, including the nature and fate of all environmental effluents, products, and process residues.

Testing for contaminants of concern and control of key parameters, some of which can be monitored continuously, are necessary to characterize the thermal desorption unit and to ensure that the unit is operated within the conditions demonstrated during the POP test. Many of these parameters are the same or similar to parameters specified in incinerator regulations because of operational and design similarities between thermal desorbers and incinerators. Some of the similarities are based on heat or thermal activity involving pollutants, mass flows of process gases, and concerns over emissions and process residues.

Proof-of-Performance (POP) Parameters:

A complete system performance evaluation which is termed a POP test is generally necessary to:

- o Demonstrate that the unit can meet performance levels (e.g., ARARs and site-specific cleanup goals);
- o Demonstrate that the unit is operated in a manner that is protective of human health and the environment;
- o Characterize residuals for future reuse, treatment, or disposal; and
- o Establish operational performance criteria to ensure compliance with performance levels and protectiveness.

Generally, a test crew experienced with evaluation of performance parameters outlined below is needed to perform the POP test.

The POP test will generally include characterization of the following waste streams: waste feed, stack gas, condensate, and residuals. Monitoring of operational parameters necessary to control the performance of the desorber (e.g., temperature, waste feed rate, etc.) as well as parameters necessary to normalize the test results (e.g., stack gas moisture and volume) will be needed to establish operational parameters and to interpret the results. POP testing recommendations are provided in Highlight 3. Additionally, pertinent 40 CFR 264 Subpart O standards should be considered during POP testing.

Small stack diameters (3-6 inches) present on some thermal desorbers present special problems with obtaining a representative sample for particulates and metals. Stacks that are within the 4-6 inch diameter range can be sampled in accordance with Method 1a in 40 CFR 60. Smaller size stacks may require method development and validation. The problem can be avoided by designing and building the unit with a large stack or by increasing the stack diameter prior to venting the stack to the atmosphere. If the latter course of action is followed, care must be exercised to ensure that the sampling port is located a sufficient distance from the change in diameter (in general the port should be at least 8 diameters distance downstream and 2 diameters up-stream from any disturbance).

Control Parameters:

Control parameters for thermal desorbers are provided in Highlight 4. The control parameters recommended should generally be monitored during the POP testing as well as during all phases of operation. Control of these parameters is prudent for many thermal desorbers to ensure the continued good performance of the thermal desorber.

RESIDUALS AND AIR EMISSIONS

Thermal desorption units generate several residual waste streams that need to be monitored and disposed of in a manner that is protective and in accordance with ARARs. The waste residuals and potential emissions are as follows:

1. Treated Solids
2. Condensate Residuals
3. Air Pollution Control Residuals
   - Scrubber Water
   - Activated Carbon
   - Particulate from cyclones, bag houses, etc.
4. Organic Air Emissions
5. Metal Air Emissions
6. Acid Gas Emissions

HIGHLIGHT 3

POP TEST PARAMETERS:

Waste Feed Characterization and Rate -
- Contaminants of Concern
- Total Chloride
- Screening Survey of Organics and Inorganics
- Physical Characteristics
- Waste Feed Rate
- Waste Feed Residence Time (See description in Highlight 4).

Stack Gas Testing -
- Constituents of Concern
- Particulates
- Metals*
- Chlorine Gas (Cl_2)
- Hydrochloric Acid (HCl)*
- Dioxins and Furans*
- Volatile Organics and Semivolatile Organics*
- Hydrocarbon (HC)
- Moisture
- Gas Volume

Residuals Testing (See listing of residuals below) -
- Constituents of Concern
- Dioxin and Furans (If applicable)*
- Metals*
- Screening survey of organic and inorganics (If applicable)

*Note - Monitoring and control of metals, as well as other organics and inorganics may be appropriate if these contaminants are present in the untreated waste stream at levels that may pose an unacceptable risk. Chlorine in the waste feed may result in metal volatilization at lower temperatures then anticipated. Organic compound formation (e.g., dioxins and furans) may occur in the thermal desorber, stack, and air pollution control devices, at temperatures of 350°F and above ("Combustion Emissions Technical Resource Document," May 1994). Well-operated thermal desorbers have been shown to produce low levels of dioxins and furans. Steps should be taken to minimize formation of these compounds during the thermal desorption process.

HIGHLIGHT 4

Residuals generated from a thermal desorber may be RCRA hazardous wastes if the waste feed was a RCRA hazardous waste, or if the residuals exhibit a RCRA characteristic. The residuals must be managed accordingly. Non-volatilized compounds may require post-treatment to achieve regulatory levels required by RCRA and/or TSCA.

1.) **Treated Solids:**

The treated solids from a thermal desorption unit must meet, or be post-treated to meet, the concentration levels required to ensure protectiveness given the management scenario specified in the Record of Decision (ROD). (The residual treatment level generally is specified in the ROD as well). The treated material must also meet specified ARARs unless they have been waived.

2.) **Condensate Residuals:**

The principle residue generated from a thermal desorber will be a liquid condensate containing primarily organics removed from the treated medium. The liquid is usually stored on-site until it is shipped off-site to an incinerator or recycler.

3.) **Air Pollution Control Device (APCD) Residuals:**

APCD residuals include scrubber water blow-down, adsorbent (e.g., activated carbon), and particulate materials that may contain organic and other constituents.

Blow-down water is usually treated by carbon adsorption, with possible pretreatment via distillation or fractionation. Rather than discharging this treated water or shipping it off-site, it is usually used to wet the treated solids to control fugitive dust emissions.

Activated carbon is often shipped off-site for either treatment and disposal (in a unit that may be subject to 40 CFR 264, Subpart X) or regeneration. Carbon regeneration may also occur on-site. Carbon is typically used as the final treatment step before the gas stream from APCDs is vented to the atmosphere. As mentioned above, carbon may also be used to treat the contaminated water so that the water can be used to wet the treated solids.

Solids and dust collected in the cyclones, bag-houses and/or wet scrubbers in a thermal desorption APCD should be considered hazardous wastes unless proven non-hazardous. These APCD solids should be analyzed before being mixed with the treated solids to avoid the potential of dilution of residual wastes. Contaminated APCD solids that contain organic contaminants of concern above specified treatment levels are generally retreated on-site via thermal desorption.

4.) Organic Air Emissions:

Emissions of organic contaminants to the atmosphere are generally expected to be low for many units due to the nature of the thermal desorption process and the use of APCDs, including the capture of organic residuals from the exhaust gas. However, the amount of emissions from a given thermal desorber is dependent upon the process design, operation, and control. Thermal desorption may result in the partial breakdown of compounds as well as the formation of others. Conditions in the unit should be maintained to limit chemical reactions due to combustion, pyrolysis, chemical reformation, or charring.

5.) Metal Air Emissions:

Metal air emissions that exceed ARARs have generally not been detected during field testing because metals are typically removed as particulates by APCDs. One exception to this finding is mercury. Mercury is expected to be released from treated wastes; APCDs can typically remove and recover a portion of the mercury from the gas stream. The APCD treatment effectiveness for mercury is unknown.

The presence of chlorine can result in volatilization of some metals (present in the amenable form in the untreated waste stream). The issue of metal volatilization is discussed and addressed in the RCRA Burning of Hazardous Waste in Boilers and Industrial Furnaces final rule (56 FR 7176, February 21, 1991.) The maximum temperatures of both the stack gas and the waste being treated need to be known and evaluated when metal air emissions are monitored and addressed.

6.) Acid Gas Emissions

There is some possibility that acid gases (e.g., hydrochloric acid, hydrogen sulfide, hydrogen cyanide, etc.) may form during the thermal desorption process. Acid gas formation is dependent on many factors, including contaminants present in the waste stream, operating temperatures, pH of the waste stream, and others. Based on a review of available literature on thermal desorption devices, acid gas formation does not often appear to be a concern during the treatment process. Monitoring during the POP test may be appropriate to verify that acid gas emissions are not at levels of concern.

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ACKNOWLEDGMENTS

This Quick Reference Fact Sheet was prepared by the Hazardous Site Control Division of the Office of Emergency and Remedial Response in coordination with the Risk Reduction Engineering Laboratory (RREL) of the Office of Research and Development (ORD). The impetus and technical support for this paper was provided by Paul de Percin, Don Oberacker, and Marta Richards (RREL/ORD).

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